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ORIGINAL RESEARCH

LOWER EXTREMITY AEROBIC EXERCISE AS A TREATMENT FOR SHOULDER PAIN

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ABSTRACT

Background: Shoulder girdle pain is a common disabling complaint with a high lifetime prevalence. Interventions aimed at decreasing shoulder pain without stressing shoulder girdle structures have the potential to improve participation in multimodal shoulder rehabilitation programs.

Hypothesis/Purpose: The aim of this study was to determine the acute effects of moderate intensity lower extremity exercise on mechanically induced shoulder pain in individuals without shoulder injury. It was hypothesized that participants would exhibit less shoulder pain, as indicated by increased pain thresholds, following lower extremity exercise.

Study Design: Repeated measures study.

Methods: Thirty (30) healthy participants were recruited to participate in this study. Pain pressure algometry was used to mechanically induce shoulder pain over the infraspinatus muscle belly. This was performed on the dominant shoulder before and immediately after performing 10 minutes of moderate intensity lower extremity exercise using a recumbent exercise machine. Heart rate and rate of perceived exertion were measured following exercise. Repeated measures ANOVA was used to compare pain pressure threshold scores between the baseline and post-exercise time points. Significance was set at $p \leq 0.05$ *a priori*. Effect size (ES) was calculated using Glass's Δ.

Results: Moderate intensity lower extremity aerobic exercise led to significantly ($F = 8.471$, $p = 0.003$) decreased evoked shoulder pain in healthy adults with moderate effect sizes (0.30-0.43).

Conclusions: Lower extremity aerobic exercise significantly decreased pain of the infraspinatus in this sample of young healthy participants. Utilization of lower extremity exercise may be of benefit for younger patients to decreased acute shoulder pain.

Level of Evidence: 2b: individual cohort study

Key Words: aerobic exercise, exercise induced hypoalgesia, pressure algometry, shoulder pain

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INTRODUCTION

Shoulder girdle pain is among the most common pain complaints with point prevalence rates ranging from 6.9 to 26% and lifetime prevalence rates ranging from 6.7 to 66.7% in the general population.[1] Specific athletic populations, throwers and swimmers, experience pain at higher rates than the general population.[2,3] Physical therapists commonly use shoulder specific exercises, manual therapy, and electrical and/or thermal modalities to assist in pain management and promote return to functional and sporting activities.[4,5] Despite these established interventions, numerous studies have demonstrated the urgency for further research regarding shoulder pain reduction. It has been reported that up to 41% of patients who sought treatment for primary shoulder complaints were still experiencing pain greater than six months following initial treatment.[6-8] It is evident there is a need for alternative treatments for pain specifically addressing the shoulder girdle.

Numerous prior studies have indicated that aerobic exercise is associated with alterations in pain perception.[9-11] This phenomenon has been termed exercise-induced hypoalgesia or exercise-induced analgesia, henceforth referred to as hypoalgesia. In general, investigators have typically found diminished pain perception, or hypoalgesia, to occur during and following many different types of exercise.[10] Emerging evidence from a recent meta-analysis of exercise-induced hypoalgesia suggests that exercise of non-painful muscles for individuals with regional chronic pain conditions produces a hypoalgesic effect and may be considered an effective method to temporarily decrease or relieve pain in painful muscles.[10] However, the concept of aerobic exercise-induced hypoalgesia has never been explored at the shoulder girdle.

Therefore, the aim of this study was to determine the acute effects of moderate intensity lower extremity exercise on mechanically induced shoulder pain in individuals without shoulder injury. It was hypothesized that participants would exhibit significant changes in pain perception of the infraspinatus following a lower extremity aerobic exercise protocol.

METHODS

Subjects

A sample of convenience consisting of 30 healthy volunteers was recruited to participate in this study. Participants between the ages of 18 and 30 years were recruited specifically to decrease the prospect of age-related degeneration of shoulder girdle structures.[12] Participants were considered healthy using the following criteria: denied any history of seeking medical care for shoulder or neck injuries and reported no current (within the prior six months) shoulder or neck pain. Exclusion criteria consisted of prior shoulder surgery or fracture, inability to perform lower extremity aerobic exercise at a moderate intensity or current treatment for any musculoskeletal disorder.

Testing Procedure

All participants completed two test sessions. The first testing session consisted of baseline outcome measures of participants' pain pressure threshold (Baseline 1), a fifteen-minute rest interval, and a reassessment of participants' pain pressure threshold (Baseline 2). Participants returned for the second day of testing 24–48 hours following the first session. Participants were instructed to refrain from performing any upper body exercises between testing sessions and to avoid aerobic exercise immediately before the testing sessions.[9] The second testing session consisted of baseline outcome measures of participants' pain pressure threshold (Baseline 3), a fifteen-minute aerobic exercise protocol, and a reassessment of participants' pain pressure threshold. Participants' final heart rate and rating of perceived exertion were also evaluated immediately following the exercise protocol.

Pain Pressure Testing

Pain pressure threshold (PPT) is the minimal amount of force required for the sense of pressure to change to pain.[13] A hand-held digital algometer (Wagner, Pain Test FP Algometer, Greenwich, CT) with a 1 cm^2 blunt tip was used for testing. Pain pressure threshold was analyzed over the infraspinatus muscle belly with the participant in prone in the anatomical position. The infraspinatus has been commonly used for pain pressure testing at the shoulder.[14-18] Testing occurred on the dominant arm as defined by the preferred hand for writing. The infraspinatus muscle belly was located by palpation inferior to the approximate midpoint of the scapular spine (Figure 1). Standardized procedures for use of the pressure algometer were

Figure 1. *Pain Pressure Threshold Testing.*

Figure 2. *Aerobic Exercise.*

performed by the same investigator for all measures, with the average of three measurements used for analysis.[13] The time between pain pressure threshold measures was 30 seconds. Training on pain pressure threshold measurement procedures was performed prior to the commencement of the study. These procedures have been demonstrated reliable and valid (ICC = 0.985, SEM = 0.453kg/cm^2) by the authors of this study.[18]

Aerobic Exercise Protocol

The aerobic exercise protocol was completed on a recumbent stationary stepping machine (NuStep TRS 400 Recumbent Cross Trainer, Ann Arbor, MI) (Figure 2). Participants self-selected a "somewhat hard" (13/20) intensity using the Borg Scale and were instructed to keep this intensity for the duration of the exercise protocol. The level of intensity was self-controlled by participants adjusting the amount of weighted resistance and cadence applied to the foot pedals. Participants were instructed to use their legs only for the exercise. Final heart rate was measured immediately following the aerobic exercise protocol using a finger pulse oximeter (OxyWatch C20, Choicemmed, Deerfield, IL)

All testing was completed in a university research laboratory and approved by the Institutional Review Board at East Tennessee State University. All participants provided written informed consent as per institutional guidelines.

Statistical Analysis

Demographic data was summarized as means (SD). A repeated measures ANOVA was used to determine the effect of lower extremity aerobic exercise on pressure threshold measures for the whole sample. SPSS version 22.0 (SPSS, Inc. Chicago, IL) was used for all analyses. The Greenhouse-Geisser correction was applied if Mauchly's test of Sphericity was violated. Significance was set at $p < 0.05$ *a priori*. Post hoc pairwise comparisons were performed if a significant effect was found. Effect size with 95% confidence interval was calculated for all statistically significant findings. Effect size (ES) was calculated using the effect size index [baseline PPT – post-exercise PPT) / standard deviation baseline PPT]. Further, individual changes in pain pressure threshold were compared to previously described minimum clinically important change scores (3.3lb/cm^2).[19]

RESULTS

Thirty (30) participants met the inclusion criteria and completed the testing. See Table 1 for demographic and exercise variables.

Table 1. *Participant Demographics.*

Participants	Number	Age in Years	Right Hand Dominant	Final RPE	Final Heart Rate (bpm)
Female	20	20.9 (1.8)	16	13.4 (2.4)	120.4 (23.2)
Male	10	19.9 (1.9)	10	13.0 (2.3)	121.0 (26.5)
Total	30	20.6 (1.6)	26	13.3 (2.4)	120.6 (24.3)

RPE= rate of perceived exertion, bpm= beats per minute

Table 2. *Pain Pressure Threshold Measures (pounds/cm2).*

Participants	Day 1 Baseline 1	Day 1 Baseline 2	Day 2 Baseline 3	Day 2 Post Exercise
Females	11.4 (3.2)	11.0 (3.4)	11.9 (5.2)	13.6 (5.7)
Males	17.3 (4.6)	16.5 (4.6)	15.6 (4.5)	17.4 (5.3)
Total	13.4 (4.6)	13.0 (4.4)*	13.2 (5.2)	14.9 (5.8)†

* Significant difference between baseline 1 and 2, p = 0.005
† Significant difference between post exercise and baselines 1, 2, and 3, p < 0.001

Table 3. *Effect Size for Significant Findings.*

Comparison	Effect (95% Confidence Interval)
Day 1, Baseline 1 & Day 1, Baseline 2	0.11 (-0.25 – 0.47)
Post Exercise and Day 1, Baseline 1	0.30 (-0.06 – 0.67)
Post Exercise and Day 1, Baseline 2	0.43 (0.05 – 0.80)
Post Exercise and Day 2, Baseline 3	0.33 (-0.04 – 0.69)

Participants rated their final perceived exertion (RPE) with an average of 13.3/20. The target for this exercise was 13/20. The final heart rate at the end of the exercise session was 120.6 beat per minutes (bpm). This represents approximately 62% of each individual participant's age-predicted maximum heart rate as determined using the maximum heart rate estimation formula (208 – 0.7 * age). [20] Mauchly's test of Sphericity was significant, thus the Greenhouse-Geisser correction was utilized. The results of the ANOVA for effects of exercise on shoulder pressure pain thresholds were significant ($F = 8.471$, $p = 0.003$). Post-hoc pairwise comparison analyses indicate that pressure pain measures at Baseline 1 was significantly less than Baseline 2 ($p = 0.005$), indicating an increased pain response after a 15-minute rest period. Further results demonstrate that the post-exercise condition was significantly higher than all baseline conditions, suggesting a decrease in mechanically induced pain ($p < 0.001$, Table 2).

The effect sizes for all significant findings are indicated in Table 3. Furthermore, 6/30 participants reported changes that exceeded the minimal clinically important difference for pain pressure threshold, indicating less pain following the exercise.

DISCUSSION

The purpose of this study was to determine the effect of distant (lower extremity) exercise on evoked pressure pain in the shoulder. Pressure threshold testing is commonly used as an objective measure of evoked pain. Mechanically induced or evoked pain is pain brought about with movement for which most physical therapy patients seek treatment.[21] The results indicate that aerobic exercise of body regions distant to the location of evoked pain, significantly decreased pain responses (increased pain pressure threshold) with moderate effects. Further, 20% (6/30) of the participants also reported changes greater than the described minimal clinically important difference for pressure threshold testing indicating a clinically relevant decrease in pain.[22] This is the first study to determine a potential hypoalgesic effect at the shoulder during aerobic exercise. These findings are similar to prior studies which have shown increased pain thresholds in response to acute and ongoing exercise albeit at other anatomic sites such as the shank, forearm or hand.[23-26] This study adds to mounting evidence that aerobic exercise can be used to specifically improve mechanically evoked pain in healthy participants. These findings also indicate a significantly increased pain response (decreased pressure threshold) between Baseline 1 and Baseline 2 with a very small effect size (0.11). This difference was also below the reported minimum detectable change (2.54lb/cm^2) for pressure threshold testing and below the standard error of measurement in this study.[22] The reason for this statistical increase in evoked pain after resting for 15 minutes is unknown. This may represent the variable nature of pressure threshold testing and is not likely of clinical value with an effect size close to zero.[27,28]

The optimal dosage of exercise to induce systemic related hypoalgesia is not known. In prior studies, a typical dose-response relationship has been described.[10,29] That being, the higher the intensity of exercise, the greater the pain relieving effect when assessing healthy participants. The self-determined dosage of exercise as "somewhat hard" was based on the standardized Borg scale. While this was consistently maintained by participants, the final heart rate the participant's demonstrated wide variability. There was likely a dose-response relationship based upon a visual post-hoc evaluation of the distribution of the data (Figure 3). Specifically, the data shows a trend line indicating that higher final heart rate was associated with a positive change in pain pressure threshold (thus an increase in the threshold), despite moderate variability in individual responses.

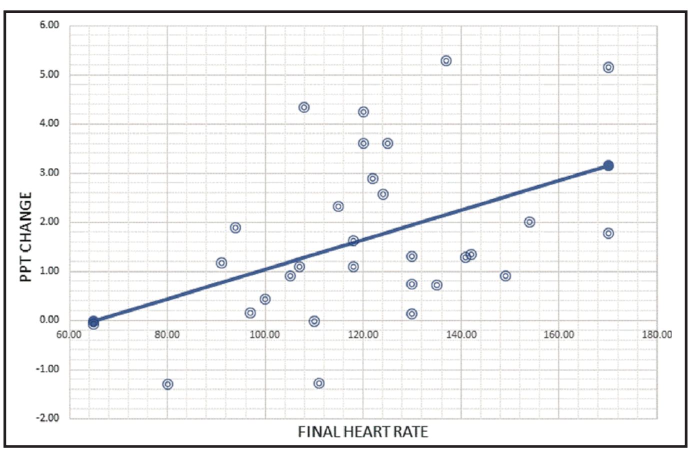

Figure 3. *Relationship between Heart Rate and Pain Pressure Threshold.*

Practically, this implies that the greater the exercise intensity, the greater the noted hypoalgesic effects. A similar dose-response relationship has been described previously[29] which noted the largest effect sizes when assessing pain perception in healthy individuals were found when aerobic exercise was performed at a high intensity (i.e. greater than 70% VO_2 max or max heart rate) yet with similar exercise duration (>10 minutes). The effects of aerobic exercise on pressure threshold in individuals with chronic pain conditions are more varied. Patients with longstanding and widespread pain conditions such as fibromyalgia or chronic fatigue syndrome have demonstrated impaired systemic pain regulatory function.[30,31] Patients with localized pain conditions, such as knee osteoarthritis, demonstrate similar decreased pain responses with distant exercise.[32] This study calculated pain responses at only one time point immediately (less than 5 minutes) following exercise. Pain relieving effects may last up to 30 minutes following the completion of the aerobic exercise.[10]

While this was not a mechanistic study, some discussion regarding of how pain responses were improved is warranted. Perhaps the most widely considered mechanism for exercise-induced hypoalgesia is that exercise creates a stimulus causing activation of descending inhibitory pain systems involving the endogenous opioids.[29,33,34] Additional basic science research has implicated a role for beta-endorphins, endocannabinoids, serotonin and/or the interactions among some or all of these chemicals which have been associated with changes in pain sensitivity.[9,35] Regardless of the complexity of the pain reducing effect, the hypoalgesic response appears to be systemic and thus the effects of exercise on evoked pain can occur at both local and distant sites.

There are many passive local pain-relieving interventions such as electrical or thermal agents and manual therapies which have the potential to decrease pain prior to, during, or following joint specific exercise. The findings in this study indicate that young healthy participants without shoulder injury exhibit decreased pain following self-determined moderate intensity aerobic exercise. Patients with shoulder injury may also exhibit a hypoalgesic benefit from distant exercise based on the systemic effect of aerobic exercise.[9] In addition to the many benefits of aerobic exercise,[36,37] distant exercise may be considered as an active hypoalgesic agent for shoulder pain. More generally, aerobic exercise could play a role as an active pain reducing modality, when otherwise not contra-indicated, as means to improve exercise tolerance and promote active self-efficacious options for pain relief. Such exercise may be more applicable to younger patients (based on the age of our sample) or athletes with acute or postoperative pain as opposed to those with longstanding widespread pain as responses to exercise for chronic pain patients are reported to be impaired.[38] Older individuals may have different responses based on reported variability in pain responses over the lifespan.[39]

Limitations

This study evaluated the acute effects of lower extremity exercise on evoked shoulder pain. The sample was selected based on convenience and was further limited to young and healthy volunteers. The response of participants of different ages, those with shoulder injury or chronic pain may differ from the outcomes of this study.[38] Evoked pain due to acute injury may differ from mechanically induced pain in healthy participants as the roles of local inflammation and tissue injury are not accounted for. Only the acute effects of the aerobic exercise protocol were evaluated. Observing the duration of these hypoalgesic effects was beyond the scope of this study. Finally, the results indicate an immediate decrease in pressure evoked pain following aerobic exercise. There are many other modalities of evoked pain which were not evaluated in this study. Future studies should consider improved methods to screen for cardiovascular health and utilize ongoing heart rate monitoring, in addition to perceived effort, to better quantify the cardiovascular loading.

CONCLUSIONS

The results of the current study indicate that pain pressure threshold measures in the shoulder improved immediately following lower extremity aerobic exercise with a moderate effect size, indicating lower extremity aerobic exercise has an immediate systemic hypoalgesic effect on evoked shoulder pain in healthy individuals. Clinicians seeking active treatment options to decrease shoulder pain might consider remote aerobic exercise.

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